Volume 1 Number 3

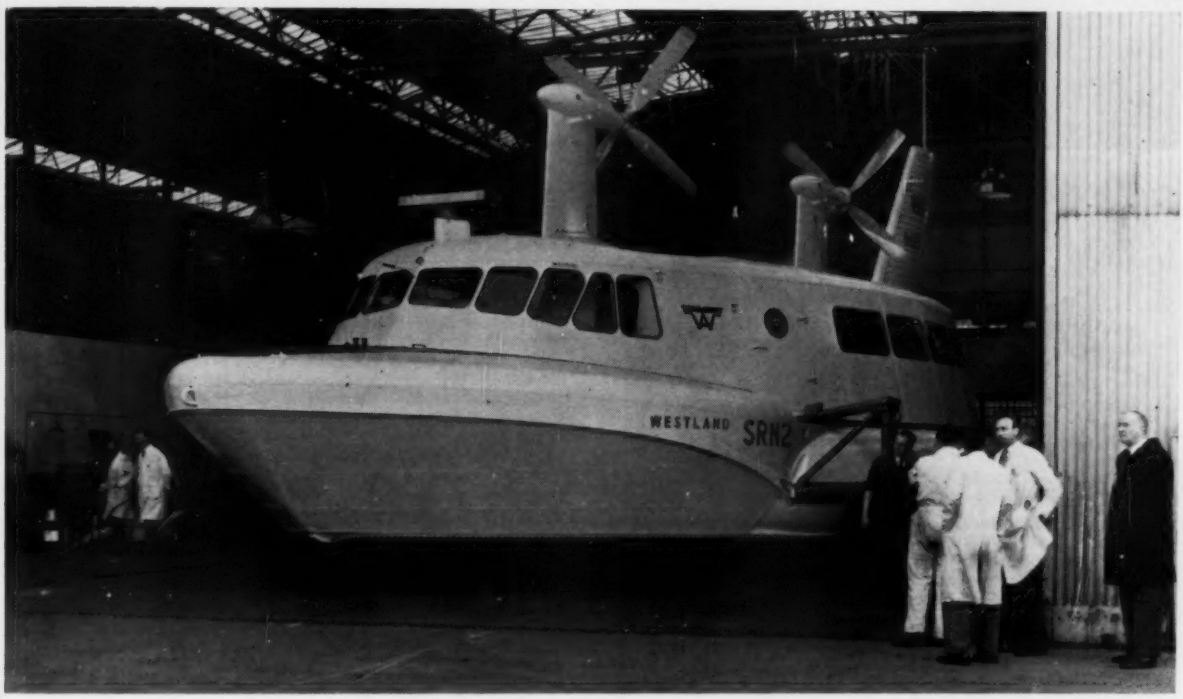
HOVERING CRAFT & HYDROFOIL

THE INTERNATIONAL REVIEW OF GROUND EFFECT MACHINES & HYDROFOILS

First Hovering Craft & Hydrofoil Monthly in the World

NEWS SUPPLEMENT

DECEMBER, 1961



Britain's largest Hovercraft, the Westland SR.N2, about to leave its hangar for initial engine runs. The craft is mounted on a three-wheeled handling chassis, designed to ease manoeuvring on the ground.

AVIATION MINISTRY BUYS CUSHIONCRAFT

THE Ministry of Aviation is instituting an applied research programme at the Royal Aircraft Establishment, Bedford, to study the possibility of using hovercraft for military purposes. They have bought, for a sum under £20,000, the experimental Cushioncraft CC-2 developed privately by Britten-Norman, of Bembridge Airport, Isle of Wight.

The Royal Aircraft Establishment will also associate with the research programme at present under way on the SR.N1 and SR.N2 developed by Saunders-Roe Division of Westland Aircraft in association with Hovercraft Development.

The Ministry states it is following closely the work now being done in developing this type of vehicle and may also participate in other projects still in preparation. Its decision follows the Admiralty announcement early in November of an inter-Service hovercraft trials unit at H.M.S. Ariel at Lee-on-Solent. These moves by the Ministry of Aviation and the Admiralty are the essential first step towards any eventual Government orders for hovercraft for the armed services.

The CC-2 Cushioncraft is a sleek 10-seater powered by a Rolls-Royce V8 car-type engine. The craft has proved to be very stable and responsive to its controls, one of its particularly noteworthy features being the very small amound of light spray created when operating over water. The vehicle is propelled and steered by thrust from the air-curtain jets, and no external propellers are used.

Britten-Norman state that the CC-2 was built as an intermediate size vehicle in response to requests from world-wide potential operators seriously interested in a relatively cheap but completely amphibious machine.

SWEDEN ORDERS NEW SEA-GOING GEM

SAAB 401 is the designation of an experimental ground-effect machine recently ordered from Saab, the Swedish aircraft company, by the Royal Swedish Navy, in co-operation with the Swedish Air Force and the Armed Forces Research Establishment, for tests over land, water and ice. It will be built by Saab's helicopter department at Norrköping and delivery is expected to take place at the end of 1962.

The craft is designed for a crew of two, but will take an overload alternative of four persons and a stretcher. The air intake is in the top of the vehicle, behind the cockpit, and has a vertical intake duct, since the design took into consideration sea conditions and ice formation.

The craft uses the air curtain principle and has a rectangular planform.

SKYDROFOIL SYNOPSIS

FROM a British designer of lightweight motor yachts comes a promising new watercraft concept which to a degree combines characteristics of a hydrofoil, a catamaran and a ram-effect air-cushion vehicle.

The designer is Brian Grimston, well known for his original applications of aluminium in small boat construction, and the new vessel he has under development is the 4-ton Skydrofoil, a 45-footer featuring a self-inclining nose foil, a main foil, and a concave-bottomed hull that uses its shape to trap and compress air beneath it when travelling at speed. Apart from providing lift, the air-cushion also serves to protect the hull from shock.

Mr. Grimston explains that because of its extremely light construction and the lift from the air-cushion, the craft can ride on quite small foils, which offers advantages when mooring and slipping. At rest the draught is only 27 inches.

The concave hull bottom provides in effect two sidewalls, in the manner of a catamaran, and this makes the craft exceptionally stable at speed. When "flying" the craft rides on the nose foil, the main foil amidships, and the aft parts of the "sidewalls."

One of the key features of the design is the Skie-Stabiliser, a self-inclining nose hydrofoil which has been under development for several years. It automatically submerges the minimum surface at the most efficient angle to lift the forefront clear of the water and maintain the hull at a fixed angle. It can be fitted with a pilot probe so that it can jump submerged flotsam which might cause damage. At present being patented, the Skie-Stabiliser is already commercially available in three sizes for ordinary planing launches up to 40ft. long. It greatly reduces pitching, "porpoising" and slamming, and also offers a useful increase in performance.

Designs have been prepared for much bigger Skydrofoils, including one powered by twin Proteus gas turbines. A feature of the larger craft will be the provision of a small auxiliary motor, shaft and propeller for reversing and slow-speed manoeuvring. At high speeds these will offer no appreciable resistance since they will be automatically lifted clear of the water. This arrangement combines the security of at least two propellers should one become damaged, with the advantage that drag, at speed, can be limited to that of a single propeller, with correspondingly greater efficiency. The cost and complication of clutches and reverse gears on the main transmission are thus eliminated. This feature also facilitates the use of light gas turbines as the main power unit at greatly reduced cost.

Mr. Grimston believes that craft based on this principle and powered by gas turbines will be able to reach speeds well in excess of 100 knots. The lift generated by the ram cushion will be such that the foils will act in the main as pure skids. However, a great deal of research and development has still to be undertaken before reaching this stage.

The first Skydrofoil is intended as a prototype for similar fast ferries, yachts and patrol or customs launches, and will act as a research vehicle from which to obtain data for the construction of larger craft. The next stage is the construction of a Skydrofoil to carry 120 passengers at speeds in excess of 50 knots. The present craft is roomy and has space for between 30 and 40 passengers.

Operating costs for the 45ft. hull with 100 h.p. engines are calculated at 4.5 pence per mile at a top speed of 17 knots; 6d. per mile at 28 knots with 200 h.p.; and 7d. per mile at 50 knots with 425 h.p. Power is at present supplied by two Perkins S6M diesels mounted in the stern.

Construction of the Skydrofoil is notable for its extreme simplicity, and is in the main from prefabricated rectangular light alloy plates with a minimum of underwater fastening. Most of the fastenings have been made with Huckbolts, waterproofed and reinforced by Araldite adhesives.

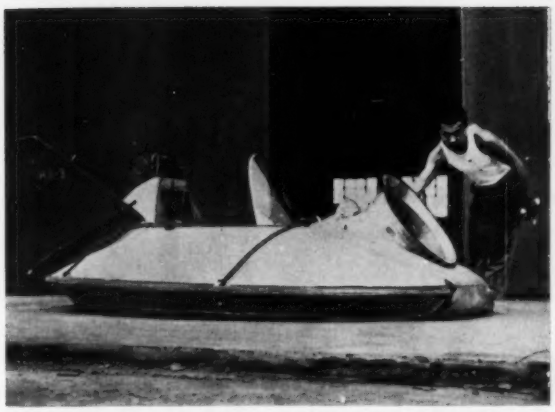
One major advantage of the Skydrofoil is its very shallow draught. This is less than half that of most hydrofoil craft and considerably less than that required by those hovercraft not propelled by airscrews. In many estuaries and wide rivers about to be developed for fast marine transport this is of outstanding value. Those who have made trips in the craft have been very impressed with its performance and stability, and we look forward to being able to record our own impressions at a later date.

The concept has attracted a great deal of attention from shipping operators in many parts, and in its developed form it promises to have an interesting future.

SKYDROFOIL SS.45
Brief Specification

Dimensions: Length 45ft.; beam 12½ft.; draught 2ft. 3in.
Engines: Two Perkins S6M with single-lever control hydraulic gearboxes.
Displacement: Less than 4 tons.
Cruising range: 180 miles.
Designed speed: 30 knots.
Propellers: Three-bladed light alloy.

This view of the Skydrofoil shows the novel Skie-Stabiliser, the concave hull bottom and the main foil.



JAPANESE GEM FAMILY

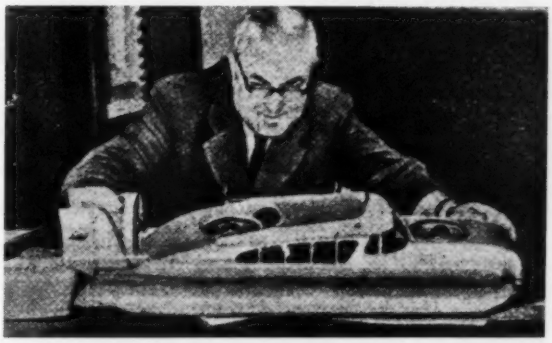
CONSIDERABLE interest in ground effect machines is being displayed in Japan, and during the past four years a number of prototypes have been constructed.

The craft illustrated here, the HC-3, is the work of Hisao Hagiwaro of Tokyo, who in 1952 formed the Jiyu Koku Kenkyusho (Liberty Aeronautical Research Institution) in order to develop a helicopter with a jet-driven main rotor. Several prototypes were constructed, but two years later the JKK was disbanded. Mr. Hagiwaro has continued his work, however, with technical assistance from the Civil Aeronautics Agency and the Tokyo Metropolitan Aeronautical and Engineering School. In recent years his work has included experiments with ground effect machines.

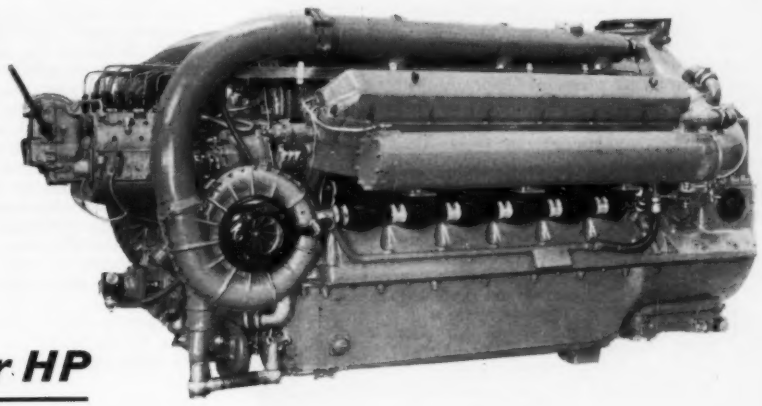
The first of these was the Kamekaze (*Turtle Wind*), a single-seater with two two-blade ducted lift units. It is said to have been built for a cost of only £120. Following this came the Kanikaze (*Crab Wind*), which was similar in shape to the Kamekaze, but it had only a single fan, mounted in an inclined duct aft of the seat. The most recent development in this series is the HC-3, with a circular body, the sides of which fold up for storage. Its single ducted fan is mounted forward of the pilot's seat.

RUSSIAN AIR-RIDER

ONE of the first indications of the shape of things to come from Russia in the air-cushion vehicle field is this model of a craft designed by the Central Naval River Ministry, Leningrad. Capable of carrying 38 passengers, the vehicle is powered by three engines, two driving the lift fans in the nose and amidships, and the third the shrouded propeller at the rear. Steering appears to be achieved through the twin rudders. Cruising speed of the craft is given as "in excess of 60 km/p/h." Length is 16.2 metres and width 6.4 metres. The craft can sail as an ordinary motor ship, and has a draught of 0.5 metres.



THE LIGHTEST
1050 HP
DIESEL
ENGINE EVER
BUILT
2 lbs. 8 oz. for HP



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DESIGN AND OPERATING PROBLEMS OF COMMERCIAL HYDROFOIL BOATS

by Baron H. von Schertel

(Supramar A.G., Lucerne)

(Continued from previous issue)

(b) Behaviour in sea waves

The behaviour of a hydrofoil vessel in sea waves is essentially the result of two functions. The first one, called "wing characteristic Z," indicates the stabilising variation (dL/dh); thus

$$Z = (dL/L_o) / (dh/b_o)$$

where

L_o = lift when travelling at normal waterline.
b_o = normal wetted span of foil between surface-piercing points.
h = depth of submergence.

The wing characteristics obtained with a surface-piercing foil in the Saunders-Roe towing tank and measurements carried out on the 60 t Supramar craft (dotted line) is presented in Fig. 10. The hump in the curve of the 60 t boat is produced by the stern-heavy trim of the boat at low speed.

In designing a surface-piercing hydrofoil the value of the characteristic Z can be influenced to a certain extent by selection of the dihedral angle, by suitable variation of foil chord, foil camber and angle of incidence in the vicinity of the piercing points. High values of Z provide for efficacious stabilisation but involve hard riding in a choppy sea. Vice versa, reducing the slope of the curve shown in Fig. 10 leads to gentler behaviour in a seaway but low stability. In order to achieve better riding comfort it is obvious that "wing characteristic" should be adapted to wave heights and wave lengths; this, however, presents difficulties with this type of foil. Nevertheless, trials which have been recently undertaken in this respect with a smaller craft and an adjustable front foil of rather simple design gave encouraging results.

In order to make a vessel with fully submerged foils stable, variations of lift as a function of h must be provided by proper variation of the angle of incidence of the foil or its flaps. The respective control device must be designed in such a way that it reacts to a change of submergence, corresponding to the same value of Z as for surface-piercing foils. The fully submerged hydrofoil, however, has a significant advantage over the surface-piercing type inasmuch as the value of Z can be changed at will whenever desirable and that a damping or filtering function can be introduced in such a manner that the foil does not react to short waves and follows the contours of longer waves only in so far as to keep the hull clear from the water surface. Furthermore, lift is being gradually modified in conformity with the signal, whereas in the case of the surface-piercing foil lift-variation occurs more or less suddenly with an impact when travelling in waves. Consequently boats with fully submerged foils give better riding comfort in sea waves. In rough sea conditions it is possible to differentiate submergence against time and to modify the foil angle reaction accordingly. The control device may also respond to accelerations; pitch and rolling angles can be reduced by means of a gyroscope stabiliser. Such type of control is difficult to materialise for surface-piercing foils on account of their high auto-stability.

The second characteristic of a foil in a seaway is its reaction to orbital motion indicated by

$$W = (dC_L/d\alpha) / C_{L_o} = \frac{1}{\alpha - \alpha_o}$$

where $dC_L/d\alpha$ = lift-curve slope. A high value of W means that a foil has a tendency of reacting strongly to orbital velocities in waves. To make a foil less susceptible to these motions it would be desirable to make the lift-curve slope as small as possible and the design-lift coefficient C_{L_o} as high as possible. Since the lift-curve slope is primarily a function of aspect ratio, its reduction is bound to increase the drag, and since, on the other had, the lift coefficient C_{L_o} is limited by considerations of cavitation and ventilation, the value of this parameter W cannot be reduced effectively.

Rigid hydrofoils are therefore always subjected to the influence of orbital wave motions. This fact is without practical consequence when running against the sea, but the influence of orbital motion is a very undesirable reality in a following sea. In such conditions a maximum reduction of lift occurs when approaching a wave-crest and—on the other hand—when approaching a wave trough orbital motions have the tendency to increase the foil's lift. Consequently the phase of the foil travel is shifted under the effect of inertia in relation to the wave-contour (by about 120°) and moves against it. Under unfavourable conditions the hull may be forced into the crest of the waves, thereby reducing the speed of the craft considerably.

The amplitude of orbital motions reduces at a progressive rate, with increasing submergence. A fully submerged foil is therefore exposed to a smaller amplitude than the average encountered by a comparable surface-piercing foil. Since—as already explained—the maximum lift coefficient will also be usually higher, a fully submerged foil suffers less from orbital motion. Apart from that, the control device can be adapted to compensate the orbital influence by corresponding variation of lift.

(c) Conclusion regarding practical applications

After having discussed the characteristics of the two basic hydrofoil systems we can make the following statements in conclusion of the first part of this treatise:

(A) Boats of the surface-piercing hydrofoil type have sufficiently low drag/lift ratios justifying their use for high-speed commercial passenger service. Under equal conditions and having equal cruising speed, they can be expected to reach a higher top speed than vessels provided with fully submerged foils. Natural stability, simplicity of construction, operational reliability, ease of handling and maintenance and, last but not least, a remarkable invulnerability of the foil-system have contributed to the acceptance of hydrofoil boats as a means of commercial passenger transportation. It can be taken for granted that the described qualities will lead to a preference for this type for use on inland waters, in coastal regions and for services within protected sea-areas.

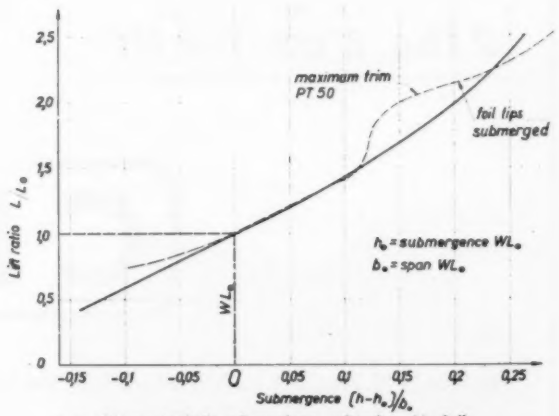

Fig. 10. Characteristic of surface-piercing V-foil

DESIGN AND OPERATING PROBLEMS OF COMMERCIAL HYDROFOIL BOATS . . .

(B) Fully-submerged foil systems are in the same drag-over-lift bracket as the surface-piercing type. They possess superior sea-riding qualities and offer higher riding comfort on account of their smaller and smoother heave and pitch response to sea waves. However, the complexity of the height- and stability-control which is needed for this type of boat must be considered to constitute a serious drawback of this system.

No doubt the electronically controlled hydrofoil boats, which have been developed in U.S.A., have shown excellent riding qualities. In spite of this fact there remains for the traditional shipbuilder the unusual conception that stability naturally inherent, from historical times, to any properly built ship, should now be subjected to the faultless functioning of a number of complicated gadgets. In case of a failure of such a control system, there may hardly remain sufficient time to cut off the automatic and to "land" the boat by hand as it is possible with an airplane. Although an unexpected sudden tilting of a commercial vessel must not necessarily result in any catastrophic situation, such an incident is liable to destroy the confidence of passengers. In consequence, the introduction of the fully submerged hydrofoil system in public service still presents problems and meets opposition of orthodox ship-owners.

Therefore the requirement exists to maintain the stability of the fully submerged foil type—similar to the surface-piercing foil—directly by dynamic forces without inserting bulky and vulnerable mechanical devices or electronic appliances. Based on ideas and experiments carried out 15 years ago by the author, a new self-controlling system is in development which—not being dependent on servo power sources and amplifiers, etc.—can be expected to offer sufficient reliability. In heavy seas the system can perform in the manner described under "Behaviour in sea waves," and there can also be introduced an additional simplified gyroscope control. A trial boat equipped with this new system is at present undergoing tests conducted by the Supramar company, and has, so far, been successful.

Undoubtedly boats with fully submerged foils will have a large field of application in the future in less protected sea areas and as long-distance ferry boats on open sea. But their range of operation will always be restricted by their faster competitor, the airplane, to which preference will be given in all cases where its travelling time between two points, including the airport feeder service, is considerably shorter.

4. Present Types of Commercial Passenger Boats

It is known that the first hydrofoil design which was used in scheduled commercial passenger services was the Schertel-Sachsenberg type. The reason for the advanced technical stage of this system lies in its structural simplicity and the reliability of the surface-piercing foils used in this type. Another reason for the perfection of these boats is due to the fact that they are the result of organised development efforts which began with the author's experiments in the thirties and which were continued through the following years without interruption. Design and construction have always been accompanied by extensive theoretical and experimental research, as well as by trials with full-scale craft. With the construction of sixteen different types and a total of nearly 60 hydrofoil boats to this date, of which 26 are passenger ferries, experience has accumulated to such an extent that Supramar's engineering staff is in the position to go ahead with the design of larger and faster economical passenger craft.

The author's experimentation with foilborne vehicles began in 1927. Over the years, a number of configurations was investigated, and most of them were found to be inadequate. The first successful, but still experimental craft, was eventually completed in 1936. Since then, further design and construction has always been accompanied by larger-scale theoretical and experimental research.

One of the early experimental craft, a 3-ton boat, built in 1939, obtained a maximum speed of 38 knots, driven by a 150 h.p. engine. During World War II, this craft was operating for demonstration and testing purposes on the lakes around Berlin, on the Rhine River and in the Baltic Sea. Among other

Fig. 11. A Supramar PT-20.

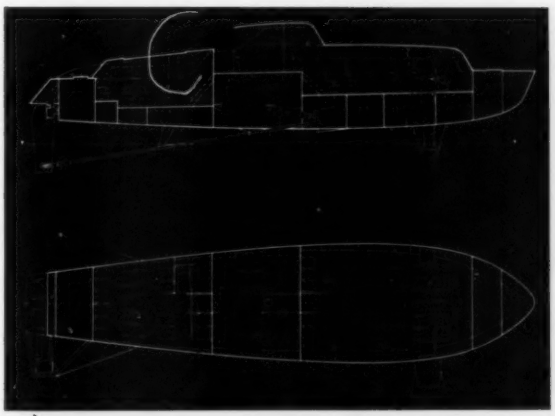

Fig. 12. General arrangement of the PT-20.

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things, a type of automatic foil control was tried out on this boat, designed to improve behaviour in sea waves.

The 17-ton boat "VS6" was completed in 1941 in the Sachsenberg Boatyard at Dessau-Rosslau. This craft, designed to be used for air-sea-rescue purposes, had a maximum speed of 47.5 knots; it was extensively trial-tested in the Baltic Sea.

The first of a series of six 6.2-ton boats (type "TS") was also completed in 1941. The last of these was equipped with a new-type drive system. The engine, placed in the hull's stern, was connected to a counter-rotating pair of propellers by means of a right-angle bevel-gear drive.

The boat "VS8" was launched in 1943 from the Gebr. Sachsenberg A.G. Shipyard in Hamburg. To this date, that craft is still one of the largest ever constructed in the foilborne field. The 105ft. long, 80-ton boat was designed as high-speed and long-range cargo carrier for operation between Sicily and Africa. Hull construction was in light alloy. A maximum speed of 40 knots was obtained, using a pair of Mercedes-Benz diesel engines, with a combined output of 3600 h.p. Although the corresponding ratio of 45 h.p. per ton is considered to be marginal for satisfactory operation, the boat was nevertheless in a position to run at 37 knots against sea waves up to 6ft. in height and 150ft. in length. It has erroneously been reported that the boat was eventually lost when failing in a following sea. The truth is that the craft stranded in a storm (in 1944) because of engine trouble. The point the author wants to make is that the disaster was not any consequence of foilborne operation. The same type of stranding could have happened, and it still might happen, to any other type of craft.

At about the time the 80-tonner was lost, construction of another hydrofoil boat was completed. Powered by a 6000 h.p. engine, this 46-ton "VS10" craft was designed to run at a maximum speed of 60 knots. A few days before the scheduled launching, that boat was completely destroyed by bombing from the air. Still another, 29ft. long, boat also designed for 60 knots, was tested at speeds up to 52 knots. Completion of the trial runs was made impossible, however, by adverse conditions during the last year of World War II.

Some time after the war, commercial application of experience gained during the Schertel-Sachsenberg development as described above was undertaken by the Supramar A.G. in Switzerland.

The first hydrofoil craft, designed to carry passengers, was completed in 1952. Named "PT-10" (with "P" for "passenger," "T" for "transport" and "10" indicating the original design weight in tons), the first boat in this class had a gross weight of 9.2 tons. A seating capacity for 28 passengers represents a payload fraction of 28%. A very interesting quality common to all boats described in this report is their tolerance as to variations in magnitude and/or location of the payload (passengers, equipment, cargo). The "PT-10," for example, was repeatedly run with the number of passengers increased by about 50%.

The two foils of the "PT-10" were designed and originally attached to the hull in such a manner that they could be raised while "flying." It was later concluded, however, that this feature was not necessary or important in practical operation.

The original "PT-10" was powered by a 500 h.p. Mercedes-Benz diesel engine MB-507, installed in the stern of the hull. Reduced-throttle cruising speed is 38 knots. Power applied in this condition is 13.2 h.p. for each of the 28 regular passengers.

Construction of a 25-ton boat was started in 1953 at the Lürssen Boatyard in Bremen. A hydraulically operated mechanism was provided, permitting retraction of the two foils. A flap was also added to the forward foil. Deflection of this flap was used in a systematic series of tests, undertaken to improve take-off as well as turning.

A boat similar in size to that in Bremen, but designed to the specifications both of the Registro Italiano Navale and the Germanic Lloyd, was built in 1955 in the Rodriquez Boatyard at Messina. This craft was to be the first of the series of very successful PT-20 boats.

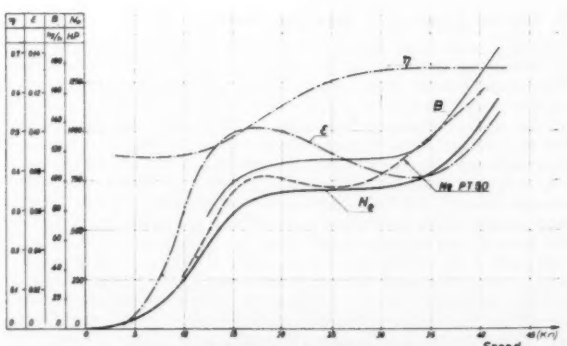


Fig. 13. Performance PT 20

DESIGN AND OPERATING PROBLEMS OF COMMERCIAL HYDROFOIL BOATS . . .

To date, two prototypes find application in established passenger lines, the PT.20 (a 27 t boat for 75 passengers) and the PT.50 (a 60 t boat for 140 passengers). The first PT.20 was built in 1955 in the Rodriquez Shipyard at Messina. This craft (Fig. 11) turned out to be the first of a series of very successful boats, 19 of which have been built or are nearing completion.

The light-metal alloy materials used in building the PT.20 hulls are Al Mg and Ag Si. Watertight compartments are provided below the passenger decks and in other parts of the hull. Several of these compartments are filled with foam-type plastic which makes these boats practically unsinkable.

The engines installed in the PT.20 are supercharged 1350 Daimler-Benz diesel engines of the type MB 820 Db. The reversible gear, placed between engine and drive-shaft, represents a special type developed by Zahnradfabrik Friedrichshafen. A 110 h.p. auxiliary engine is located in the stern of the hull for emergency operation. Driving a small separate propeller, this engine can be used to manoeuvre the boat in displacement condition.

The general arrangement of the PT.20 type is shown in Fig. 12. The boat is operated and the machinery controlled entirely from the bridge, which is located above the engine room. Forty-five passengers can be accommodated in the forward cabin whilst the rear cabin is somewhat smaller and can take 30 passengers.

Together with the struts and a horizontal girder, each foil forms a uniform framework which— apart from giving static advantages—facilitates the exchange of the foil structure. The foils themselves are made from medium steel as shells welded at the seams. The forward foil can be tilted within narrow limits by means of a hydraulic ram acting on the girder across the hull. It is therefore possible to adjust the angle of attack of that foil during operation, thus counteracting the effect of larger variations in passenger loads and to ensure optimum behaviour in sea waves.

PT.20 can be considered to be the smallest type of foil-borne craft suitable for passenger-carrying coastal service. In view of its novel and unconventional characteristics, the first boat of its class was originally licensed as "experimental" and restricted to operation in a six-mile zone off the coast of Italy. After frequent inspections and supervision of the service, the Registro Italiano Navale extended the licence in 1958 to operation within a 20-mile coastal zone, and in 1960 within a 50 miles limit. Today the PT.20, as well as the PT.50, have been classified by the authorities of several countries.

Technical data which have an influence on the profitable operation of the type PT.20 are presented in Fig. 13. The shaft power of the engine was measured during operation by means of a torque-meter. The propeller was model-tested, thereby taking proper account of the influence of shaft inclination. The drag lift ratio was then derived from net power. This ratio is $D/W = 8.6\%$ at cruising speed (38 knots) and its minimum is 7.7% at a speed of 34 knots. The corresponding maximum lift-over-drag is $W/D = 14.3$.

A special type of PT.20 was designed for the transportation of engineers and workers to the offshore oil-drilling and pumping stations for oil-producing organisations (Fig. 14). In this type, bridge and engine room have been arranged in the fore-ship in order to obtain better vision, since tropical waters have an occasional influx of driftwood. Tropical conditions were taken into consideration in the design and installment of the engine plant, and the propeller has been placed in a specially protected position. Because passengers board and leave this boat via the aft-ship, this part has been fitted with particularly sturdy metal guards. As these boats are undergoing very rough handling by their native crews, the requirements with regard to their performance, sturdiness and a minimum of maintenance are extremely high. Thus the boats must be able to remain foil-borne even when sudden full rudder is applied at full speed. Boats of this special 29 t type have been constructed at the Gusto Shipyard at Schiedam (Holland) for the Shell Petroleum Company in Maracaibo.

Fig. 14. A special variant of the PT-20 —the Gusto-built Supramar PT-27, which is used for transporting staff to off-shore oil drilling stations in Venezuela.

Hydronautical cosmonauts: From right to left, the Sputnik, Meteor and Raketa show their paces up the Volga, watched by their designer, R. Y. Alexeyev, who evidently intends that Russia will not lag in the hydrofoil stakes.

SPUTNIK

RUSSIA'S 300-SEAT HYDROFOIL

LAST month we made brief mention of the hydrofoil vessel Sputnik, built at the Krasnoye Sormovo Shipyard at the port of Gorki, on the river Volga. Construction details have now been made public.

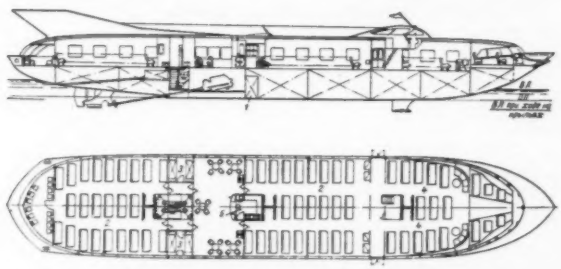
Built for service on inland waters only (which include, in the U.S.S.R., some very large lakes such as the Caspian Sea and Lake Baikal, and others which have been, or are being, created artificially), the Sputnik has been designed to comply with requirements laid down for an experimental class in Category "O" of the River Register of the Russian Union of Federated Soviet Republics. Her hull lines, together with the foils, provide high cruising quality combined with adequate stability both in calm water and waves. She will remain buoyant with any two adjacent fore compartments, or any one of the hull compartments, flooded.

Relative lightness is achieved by the adoption of an all-welded hull (the earlier types had riveted hulls) made of an aluminium magnesium alloy known as AlMg-61, and by the extensive use of plastic materials in the superstructure, whilst strength is assured by the use of special profiles in the pre-fabricated sections of the hull, and corrugated materials in the internal partitions and superstructure carrying fuel and lubricants to provide for a cruising range of 500 miles at an average speed of 43.5 knots, her principal particulars are as follows:—

Length	47.9m.	157ft. 2in.
Breadth of deck	9.0m.	29ft. 6in.
Draught, at rest, i.e. full	1.28m.	4ft. 2.5in.
Draught, in motion, i.e. on foils	0.9m.	2ft. 10in.
Displacement at full load ...	110 tons.	
Engines	4 x 850 h.p.	
Cruising speed at full load ...	41.4 knots	
Maximum speed	49.7 knots	
Number of passengers:		
Long-distance trips	260	
Short-distance trips	300 (approx.)	
Number of crew	5	

Passengers are accommodated comfortably, seated in three saloons in the superstructure to which they gain access over a space between the fore and central saloons. Walking space is provided for on the aft-deck. The fore saloon is entirely glazed, affording an excellent view, and accommodates 68 passengers; the central and aft saloons have accommodation for 96 passengers each, this number being increased to 108 for short-distance trips by the substitution of padded benches for the aircraft-type padded seats provided for long-distance trips. A buffet is provided, with a store-room below in the hold, and also special hanging space for overcoats, etc., and a rack for heavier baggage, with side racks above the windows for light articles. Two cabins are provided for the crew, who are, however, expected to live ashore between trips. Natural ventilation for all these spaces and for all working space is provided for by cowls, heated by a hot-water system maintained by its own heaters. They are insulated against heat and sound, and fitted out in fire-resistant materials. The deckheads and internal bulkheads are painted tastefully in light colours. The water supply is separate for drinking and washing purposes, the former being carried in a hygienic tank of about 400 litres (88 gallons) capacity, whilst the latter is merely pumped in from outside through a strainer.

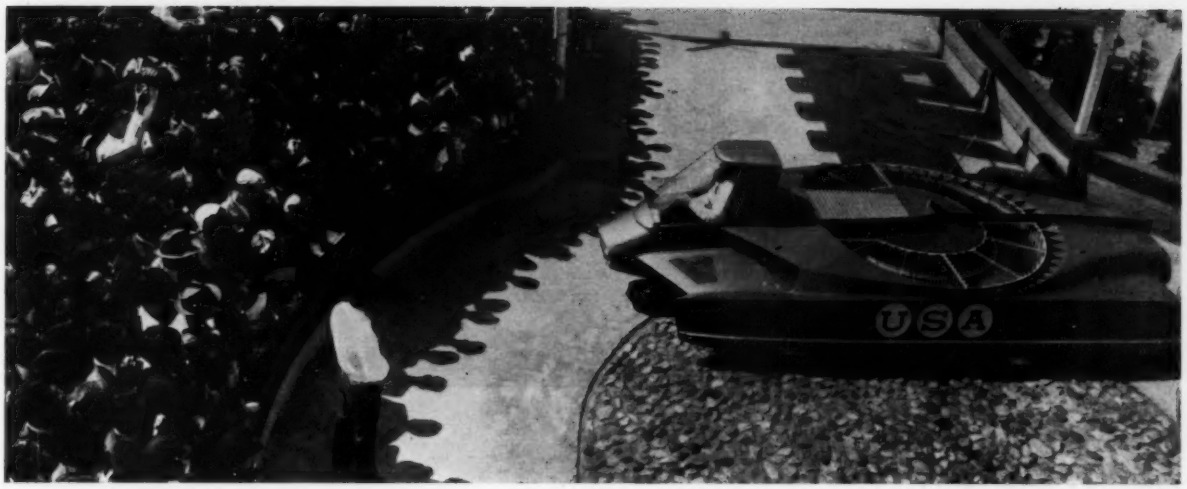
The Sputnik is navigated from a forward wheelhouse, whence there is electro-hydraulic control of the rudder and main engines consisting of four diesel motors, type M-50, each developing 850 h.p. The latter are subject also to local control from a central platform in the engine room with all the usual instrumentation. The auxiliary power plant consists of a combined diesel motor, electric generator, compressor and pump, serving multiple purposes, producing electricity, providing compressed air for starting, pumping out the bilges and warming up the main engines in cold weather. The electricity supply is at a voltage of 24–26 volts and is run along a single lead, the body of the hull being used as the return lead. It is produced, alternatively, by four generators, type GSK-1500, run off the main engines by the generator type KG-5.6, in the auxiliary power plant by batteries of acid accumulators, type 6STK-180.



General arrangement of the Sputnik.

Telephonic communication is provided between all important positions in the vessel and the command post in the wheelhouse, which has a radio telephone type R-807 for external communications, as well as a motor-car type transistor receiver type A-13 with loudspeaker extensions for the benefit of passengers.

Safety provisions include the pump in the auxiliary power plant, which has a capacity of 20 cubic metres (235 cubic feet) an hour, and an auxiliary hand pump, type RN-20, which can be used for pumping out the engine room. The engine room is fitted with a powerful CO_2 extinguisher, and the wheelhouse and passenger saloons are equipped with hand-worked foam and CO_2 extinguishers. Foam lifebelts are provided for all passengers and members of the crew, in addition to eight life-buoys and two inflatable rubber boats. There is a single Matrosov anchor, worked by an electric capstan with a pull of 400 kg. (882 lbs.).



Aeromobile 200-2 in Tokyo.

AEROMOBILIA

ONE of the star United States exhibits at the trade fairs held in Tokyo, Turin, Zagreb and New Delhi this year has been the 18-foot long Aeromobile 200-2, latest of a series of successful ground effect machines designed and built by Dr. William R. Bertelsen, of Neponset, Illinois.

A talented engineer as well as a general practitioner, Dr. Bertelsen built some of the first man-carrying cushion craft, and is one of the best-known proponents of these vehicles. His experiments with vertical lift machines began ten years ago and were motivated largely by his need for a vehicle able to traverse ice and snowbound roads. The initial and operating costs had to be within reach of a country doctor, so a helicopter was out of the question.

The A-200, a forerunner of the craft exhibited, burns at full throttle about 9 gals. of 80-octane aviation fuel an hour and costs about $3.60 for 60 minutes' use, which is sufficient time to make half a dozen calls over ice-bound or flooded roads. Dr. Bertelsen believes that if vehicles of this type were mass-produced they would cost only two-thirds as much as a family car.

From his original craft, which was the size of a large sleigh and powered by a Richter engine, he developed the Aeromobile 200 and then the 200-2. The latter has been built specifically for the U.S. Office of International Trade Fairs, U.S. Department of Commerce, to demonstrate overseas that practical achievement in the GEM field can be found amongst U.S. amateur engineers in their small workshops, as well as among the large companies which are able to invest in costly research.

Dr. Bertelsen and his assistants are based in a building which his father formerly operated as a machine shop. Apart from the Aeromobile family, they are developing a series of ram-wing GEMs called Arcopters, and the Aeroplow, which uses compressed air blasts to improve plowshare scour.

Aeromobile 200

Powered by a 178 h.p. Franklin 6V-178 6-cylinder air-cooled helicopter engine driving an eight-blade fan, the Aeromobile is constructed from aircraft alloy steel tubing covered with aluminium sheet and fibreglass. It has a gross weight of 2,700 lbs. (four passengers) and carries a useful load of 1,080 lbs. The hover height at the gross weight is 12 inches and the top speed is 60 m.p.h.

Control is effected through aluminium flaps surrounding the base, which are operated by a four-position stick. The flaps control the angle of the peripheral jet discharge and the local volume of the jet. Propulsion is achieved by tilting the machine in the desired direction by means of the control flaps which will cause it to move rapidly forward, backward or sideways. Pivot turns and yaw control are produced by differential deflection of the front and rear sections of the side flaps, and braking is accomplished by rearward tilting, which produces reverse thrust.

I am much impressed with the first issue of "Hovering Craft and Hydrofoil." I shall await the next issue and the next with pleasant expectancy. As the field of the ground effect vehicle evolves and becomes more predictable, it will be interesting to look back through the early issues to trace its evolution. It is good to have one periodical in which can be found the latest in hardware and theory in Hovercraft. Until now the news in this specialised field was widely scattered in aircraft and boating publications.

Much success to you.

WILLIAM R. BERTELSEN,
President, Bertelsen Manufacturing Company, Inc.

The Aeromobile 200 on test.

AEROMOBILIA . . .

For the following description of how the craft handles we are indebted to *Science and Mechanics*:

"The feeling—as you break from earthbound friction—is eerie. It's as though the A-200's flap-rigged undercarriage were greased. 'Greasy' in fact is how Dr. Bertelsen describes the take-off sensation, and it fits.

"With the A-200 'greasy' you're ready to test the controls which, through rods and cables, manipulate the six flaps. Two flaps—each 67in. long and 8in. wide—are hinged along each side and hang vertically from the craft's base. Front and rear flaps are the same width, but longer—about 83in. All six control the fan's downward ducted peripheral airstream.

"Foot pedals control opposing sets of tandem flaps to make the A-200 spin clockwise (right pedal) or counter-clockwise (left pedal) on its own axis.

"The four-position stick—left, right, forward and rear—controls forward speed, reverse and tilting. Tilt the A-200 either to the left or right and it goes in the direction of the tilt.

"Tilting does more than merely control the directional thrust. It helps balance out eccentric loads (any off-kilter weight distribution). Tilting also offsets the effect of cross-winds, permits the A-200 to climb slopes as steep as 20° and, in high-speed turns, holds the craft to a curve.

"Hold both pedals steady and push the stick forward, and the A-200 moves forward, picking up speed. Pushing the stick forward angles the front flap inward and tilts the air car slightly nose-down. Although the tilt is scarcely discernible, it creates thrust that propels you forwards.

"Pull back the stick and, rearing on its haunches with tail down, nose up, it brakes to a stop. Not as fast as power brakes, it nevertheless brakes fast enough for normal 'flying.' Hold the stick in reverse and the A-200 moves in that direction.

"At full throttle, both fan and engine speed deliver some 100,000 cu. ft. of low pressure—0.10 lb.psi—air per minute. The flaps control this constant air-cushion by giving it direction.

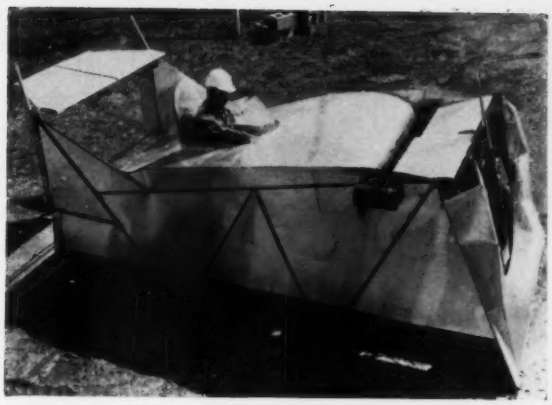
"Forward speed depends on how much direction you give the airstream. Flaps are controllable through an 85° arc—55° negative when sucked in from vertical and 30° positive when angled outward. The greater the angle of your flaps, the greater control over the airstream and the faster your speed.

"You might think that when a portion of the total airstream is diverted from lifting to propulsion—as in forward flight—there would be less cushioning and slightly less altitude at higher speeds. Actually, the A-200 gains a bit of altitude because of the so-called "ram-effect" of high velocity air. Acting as a ram beneath the fan, it lifts the car to an inches-higher altitude.

"We didn't find tilting objectionable. In fact, tilting is more noticeable to the ground observer than to riders. The tilt when the air car sidles in sideways to park between two cars isn't at all noticeable. Nor is it uncomfortable on relatively slow curves we attempted.

Dr. Bertelsen at the controls of the Aeromobile 200-2.

AEROMOBILIA . . .



The Arcopter GEM-1 ram wing, showing the combination of canard vertical and horizontal surfaces and conventional tail surfaces.

"Degree of tilt depends on altitude. At a hovering height of 12in. it's impossible to tilt more than about 20° without hitting the ground with the low side. Ideally, a peripheral jet car should ride high enough to 'out-tilt' slopes. With a maximum 20° tilt, it's limited to a slope of the same angle, although Dr. Bertelsen claims that by clever handling the car can climb hills ½° steeper."

Dr. Bertelsen believes that there is a tremendous future for the overland application of ground effect machines, and feels that the Aeromobile can free people from bondage to conventional roads. He stresses that suburbs could preserve rural beauty with nothing but broad, grassy expanses leading from one town to the next. A clear, fairly level expanse of grass makes the ideal Aeromobile highway, and such highways would be so cheap in comparison to concrete roadways that a network could be spread over enormous areas.

Grass Airways

He says a grass paved airway would be much better—faster, safer and more efficient—if it were shaped into shallow grooves. The Aeromobile centres itself in the groove, tests have shown, and moves steadily forward without steering.

An eight-lane airway would be about 80 feet wide, the right-of-way now needed for four lanes of auto traffic. The parallel grooves, each about 18 inches deep and 10 feet wide, would accommodate 8-foot wide vehicles. A driver would move to successively faster lanes toward the centre as his speed rose. The outer lane should handle speeds to 50 m.p.h., the second lane 75 m.p.h., the third 100 m.p.h. and the innermost lane 150 m.p.h.

Ram Wings

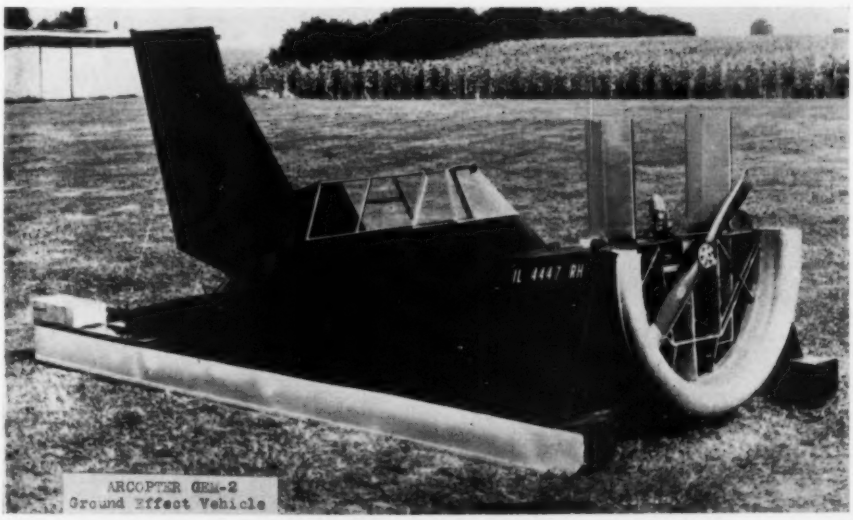
Initial experiments with ram-wing GEMs have indicated that these vehicles are surprisingly stable both statically and dynamically, despite a lack of the full range of conventional aircraft stabilising surfaces. Certainly interest in the ram-wing GEM in growing, and Dr. Bertelsen is devoting a great deal of energy to the development of these craft.

The first two Bertelsen ram-wings are the Arcopter GEM-1 and -2, the first a single-seat craft powered by a 65 h.p. Continental and capable of 40 m.p.h., the other a two-seater fitted with a 72 h.p. McCulloch O-100-1 and with a maximum forward speed of 45 m.p.h.

Specifications for the two craft are as follows:—

Arcopter GEM-1: Empty weight, 750 lbs.; gross weight, 900 lbs. with pilot); length overall, 14ft.; width overall, 6ft. 8in.; height to prop tip, 6ft. 6in. Construction: Aircraft alloy tubing and aluminium sheet. Control: Canard vertical and horizontal surfaces and conventional tail surfaces combined. Performance: maximum hovering altitude at 900 lbs. gross weight, 2in. Max. attained top speed: 40 m.p.h. Max. grade climbing, about 20%. Operating terrain: any unobstructed surface—grass, roads, open water, snow, ice, swamps, tundra, sand.

Arcopter GEM-2: Empty weight, 760 lbs.; gross weight 1,100 lbs. (two passengers); maximum useful load, 400 lbs. Leigth, 18ft. 9in.; width, 92in.; height, nose 3ft. 5½in., tail 7ft. 5in. Performance: max. forward speed, 45 m.p.h.; altitude. 2in. at zero speed, 4in. at top speed. Construction: Aircraft alloy steel tubing, aluminium sheet. Control: Canard control surfaces at the nose, conventional control surfaces at the tail. Flotation: 1,500 lbs. displacement.



The Arcopter GEM-2 which has attained a maximum forward speed of 45 m.p.h.

HOVERCAR PLAN ANNOUNCED

HOVERCRAFT DEVELOPMENT LTD. has started the design of a 300 m.p.h. "Hovercar" which could carry 150 passengers from Marble Arch to the Arc de Triomphe in sixty minutes.

Heading the project is Christopher Cockerell, inventor of the Hovercraft, and a team of scientists from the HDL experimental base at Hythe, near Southampton. This firm is a subsidiary company of the National Research Development Corporation, the government-sponsored body which backs British inventions.

The Hovercar would skim half-an-inch above a specially prepared track. Weighing 43 tons, the machine would cost £150,000.

A spokesman for the N.R.D.C. made these comments:

"We foresee the Hovercar as a form of transport which could be widely used for high-speed travel between city centres.

"It could help to ease the growing problem of traffic congestion on the roads, and large numbers of people could be carried over long distances quickly, comfortably, and economically.

"If British industry takes up the idea, the first 150-seat Hovercar, we believe, could be built and operating within four years."

Operating on the same principle as the Hovercraft, the machine has a suspension system and lift pads on its underside. The pads employ jets to generate and sustain the air cushions which support the vehicle.

It could be used for fast non-stop passenger services between city centres at speeds of 200 to 300 m.p.h. or, at slower speeds, and with an increased passenger load, it could provide underground commuter transport. The "cars" could be linked together to form "hovertrains."

If a Channel link, either by bridge or tunnel, becomes a reality, then the machine could carry passengers between London and Paris in just over an hour.

Hovercars could range from small 50-seat passenger cars to large double-deck vehicles for several hundred passengers or an equivalent load of cars or freight.

Experiments on a suitable type of propulsion for the Hovercar are being carried out under Dr. Eric Laithwaite at the Electrical Engineering Department of Manchester University. He is working on a linear electric induction motor, a form of motive power which appears to be suitable for the Hovercar.

Other forms of propulsion, including propellers, may be considered, but the linear electric induction motor has the added advantage of having no moving parts and quiet operation.

Terminals could be built over existing ones and the Hovercar could travel in and out on its own overhead track.

The first result of work being carried out at Hythe could be the operation of a small manned vehicle on an experimental track.

The first commercial application might be on a relatively short route to obtain operating experience. For example, London to London Airport, which could be followed by an intermediate stage service between London and Birmingham. This could then lead to the opening of a direct London-Scotland run.

HOVERING CRAFT & HYDROFOIL

DECEMBER 1961 VOLUME 1, NO. 3

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HOVERING CRAFT AND HYDROFOIL is produced by Kalerghi-McLeavy Publications, 18 Barter Street, London, W.C.1. Telephone: CHAncery 2413. Cables: Daytonpres, London, W.C.1. Printed in Great Britain by Charles Elphick Ltd., Biggleswade, Bedfordshire. Annual subscription: Five Guineas U.K. and equivalent overseas. U.S.A. and Canada $15. There are four main issues and eight printed news supplements annually.

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T.M. the Emperor and Empress of Japan looking at the scale model Supramar PT-20 hydrofoil displayed by the Supramar licensee, Hitachi Zosen Shipbuilding and Engineering Company.

PT-20 HYDROFOIL FOR JAPANESE SIGHTSEEING SERVICE

HITACHI Shipbuilding and Engineering, a Supramar licensee, recently concluded a contract with Aichi Kankosen (Aichi Sightseeing Vessel Co. Ltd.) to deliver the first PT-20 hydrofoil vessel now being built at Kanagawa Shipyard, in April of next year. H.S.E. is scheduled to conclude similar contracts with Kansai Kisen and Nankai Kisen. The first PT-20, which accommodates 76 passengers, whose building price is 98 million yen, will be allocated to the Nagoya/Gamagori/Irakosaki/Toba Sightseeing Service.

In July 1961, H.S.E. announced a production programme providing for the building of five PT-20 hydrofoil vessels by the end of April 1962.

LIFT FANS

GENERAL requirements for lift fans are low weight, flat head-flow characteristics, high efficiency, long life and low cost. Under certain circumstances the centrifugal fan possesses advantages over an axial fan, but during the last two years Dowty Rotol Ltd., of Staverton, Gloucestershire, have carried out extensive study into the application of fixed pitch and variable pitch axial types of fans as well.

The Dowty Rotol Centrifugal Impeller is of glassfibre and steel construction with a spoked central wheel which gives it a light rigid structure, a typical 5ft. diameter impeller absorbing 130 h.p. weighs 70 lb.

The objects of this form of construction are low weight and the ease with which damage to the fibreglass structure can be repaired. Erosion and stone damage to the blades are prevented by a light stainless steel sheath.

Evidence so far accumulated after considerable design and development work on this form of construction, both during rig tests and under actual operational conditions, confirms its suitability for hovercraft application. Fans up to 12ft. in diameter, absorbing 1,500 h.p., delivering 13,000 cu. ft./sec., with heads ranging from 50–90 P.S.F., are at present under construction.

The characteristics of an impeller are designed to match a specific installation, but in general, efficiencies of the order of 80 per cent are readily obtainable by the use of the appropriate aerofoil blading and careful aerodynamic design.

Wide variation in volume flow is possible with only a comparatively small change in head and efficiency. These features are important in hovercraft applications and can have considerable influence on the stability of the craft as a whole.

In addition to the impeller itself, Dowty Rotol are currently supplying transmission gearboxes for a number of hovercraft. These boxes, transmitting power from the engine to the impeller, usually through a right-angle drive and shafting, embody the experience gained in the field of aircraft accessory drive boxes.